U.S. Department of Energy

Tomorrow's Energy Today

for Cities and Counties

Keep It Cool with Thermal Energy Storage

Here comes summer. Temperatures are rising, but energy costs aren't, thanks to an innovative way of storing nighttime off-peak energy for daytime peak use—cool thermal energy storage.

In most states, demand for electrical power peaks during summer. Air-conditioning is the main reason, in some areas accounting for as much as 50% of power drawn during the hot midday hours when electricity is most expensive. But during the night, utilities have electricity to spare, and this "off-peak" electricity is much cheaper. Now there's a way to air-condition during the day using electricity produced at night.

Cool thermal energy storage (TES) has become one of the primary solutions to the electrical power imbalance between daytime need and nighttime abundance. Although "cool thermal energy" sounds like a contradiction, the phrase "thermal energy storage" is widely used to describe storage of both heating and cooling energy. Heating TES usually involves using inexpensive, off-peak power to add heat to a storage medium for later use.

In contrast, cool TES uses off-peak power to provide cooling capacity by extracting heat from a storage medium, such as ice, chilled water, or "phase-change materials." Typically, a cool storage system uses refrigeration equipment at night to create a reservoir of cold material. During the day, the reservoir is tapped to provide cooling capacity.

There are many advantages to using a cool TES system. Lower nighttime temperatures allow refrigeration equipment to operate more efficiently than during the day, reducing energy consumption. Less chiller capacity is required, which means lower capital equipment costs. And by using off-peak electricity to store energy for use during peak hours, daytime peaks of power consumption are reduced, forestalling the need to build expensive new power plants.

James Caccavo / PIX 1302

Patrons at the Pasadena Central Library can enjoy a good book and cool air despite stifling summer temperatures. The library uses a cool storage system to keep energy costs down during daytime peak use.

"Cool storage is a dynamic way to gain summer peak capacity by shifting the on-peak load to off-peak hours."

— Moudood Aslam
Conservation Specialist
Pasadena Water and Power

Cool Storage Using Ice

Ice is an efficient cool storage medium. Cool storage systems using ice can store and release 144 British thermal units (Btu) per pound (334,000 joules per kilogram) during melting and freezing, whereas chilled water systems can store only about 18 Btu per pound (41,780 joules per kilogram)—about one-eighth the capacity per pound of an ice storage system.

Pasadena, California

The city of Pasadena, California, is installing ice storage systems in two of its buildings, the Pasadena Central Library and the Pasadena Civic Center. It's Pasadena's way of taking the lead in the Commercial Cool Storage Incentive Program the city started in 1992 to promote cool storage systems in the community.

"We're certainly putting our money where our mouth is," says Moudood Aslam, conservation specialist at the city-owned utility, Pasadena Water and Power. "The city's resource plan anticipated a shortfall of electricity around 1996 or 1997. To prepare for that, we can either build new power plants or shift power loads and conserve energy. We encourage customers to both shift and conserve. Cool storage is a dynamic way to gain summer peak capacity by shifting the on-peak load to off-peak hours."

The utility goes even farther to promote cool storage, paying an owner as much as $5,000 for a building's cool storage feasibility study. The utility also pays a rebate on cool storage installations; the rebate amount is based on the number of kilowatts shifted from on-peak to off-peak hours, up to a maximum of $250,000. Pasadena also markets cool storage to building owners through direct-mail brochures and personal contacts.

Utilities such as Pasadena Water and Power let customers decide which cool storage medium is most advantageous to them. A potential benefit of ice is that it's generally colder than chilled water or phase-change materials, unless the chilled water is treated with an additive. A cooler storage medium produces cooler air, so less air needs to be moved to cool a building. Because fans that move the air can be smaller, they cost less and use 30% to 40% less energy than a conventional system does, according to Electric Power Research Institute. Also, duct size can be 20% to 40% smaller and air handlers 30% to 50% smaller, requiring less initial equipment cost and less cost for the building space needed to house mechanical equipment.

Lincoln Electric Goes for the Cold

Utilities have their own reasons for using ice and chilled water storage systems. Feeding the cold air from these systems into a turbine can boost

Homes and Small Commercial Buildings: A Coming Market

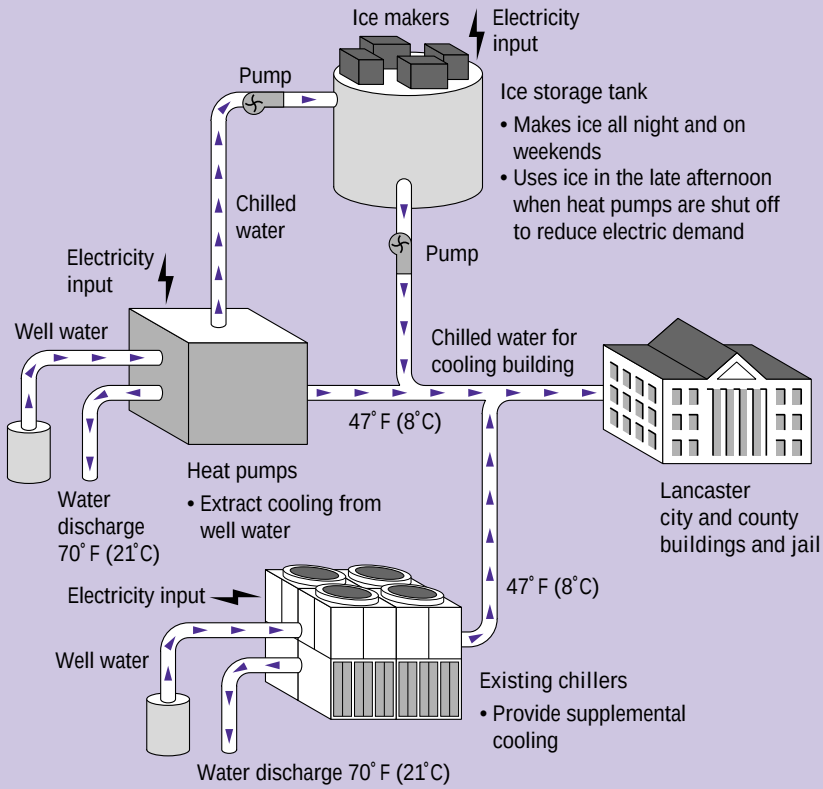
Ice is now well established as a cool storage medium for larger buildings. But it can also store cooling power in a small space, and that's opening new opportunities in homes and small commercial buildings. As of mid-1994, 518 residential units in Sacramento, California, had installed ice storage systems and collected cash rebates on the installations under the Residential Thermal Energy Storage Program of the public power utility, the Sacramento Municipal Utility District (SMUD). Because these residential systems also heat domestic water and provide space heating in winter, they can provide a total annual energy savings of about 5000 kilowatt-hours (in a residence of 1500 to 1700 square feet [140 to 158 square meters]), compared to an all-electric residence with electric resistance space heating, water heating, and central air-conditioning. This amounts to an annual savings of about $800 to the home owner.

The benefit? The average residential ice storage system shifts 2 to 3 kilowatts of summer peak load and about 3100 kilowatt-hours per year off-peak, which is worth approximately $6,200 to SMUD in avoided power costs (present value) over 20 years. This means that just 1000 residential ice storage systems would save SMUD roughly $6.2 million.

This Sacramento home (above) benefits from a cool storage system. These systems are integrated units that provide three services: hot water, space heating, and air-conditioning. The systems can be built-in or located in a side yard.

Phenix Energy Systems / PIX 1300, 1301

How Cool Storage Works in Lincoln



During the summer, heat pumps remove heat from the buildings and transfer it to underground water wells. During the cooler late evening and early morning hours, when electricity is less expensive, the heat pumps act as high-efficiency ice makers. This ice is stored to cool the buildings during the afternoon, the peak demand period. Chillers are available to provide supplemental cooling on the hottest days and may also be used for cooling buildings in off-peak periods while the heat pumps are making ice.

Savings on energy costs for Chicago's annex to McCormick Place is expected to approach $1 million by 1997.

energy production. Combustion turbine generators activated by utilities to provide extra power during peak demand are, ironically, least efficient in hot weather. As a turbine's air inlet temperature increases, air density decreases, and generating capacity falls. Lowering that air inlet temperature increases efficiency tremendously, producing more power.

Lincoln Electric System, the city-owned utility of Lincoln, Nebraska, uses an ice storage system to cool inlet air on a 57-megawatt turbine at its Rokeby Station. On a day with a temperature of 100˚F (38˚C), the cooling increases the turbine's capacity by 25% compared to that with no inlet cooling, and at no net increase in operating costs.

Lincoln also uses ice storage downtown to cool 330,000 square feet (30,660 square meters) in the city and county administration building and the Lancaster County Jail. The utility also will use the system in a new 120,000-square-foot (11,150-square-meter) records-storage and office building.

Lincoln took an innovative approach to building and operating its downtown cool storage system. In 1989, the county and utility formed the District Energy Corporation to govern the city and county heating and cooling system. This nonprofit corporation provided the financing to build the ice storage system as part of a district energy system. Lincoln Electric contracts with the corporation to handle management and maintenance.

Chilled-Water Cool Storage

One advantage of using water as a cool storage medium is that constructing chilled-water storage tanks is economically attractive in larger buildings.

Chicago's McCormick Place

One of the world's largest cool storage systems is located at Chicago's McCormick Place exhibition center. Chicago's Metropolitan Pier & Exposition Authority chose chilled-water storage for a new annex to McCormick Place. The 2.2-million-square-foot (204,400-square-meter) annex is slated for 1997 completion, but by 1994, McCormick Place was already using off-peak power to store cooling capacity in the new 8.5-million-gallon (32-million-liter) chilled-water tank and apply it by day to cool the center's existing two buildings.

Adding the annex could have meant three separate mechanical systems for the three buildings. Instead, the storage tank is part of a $40 million project to put the entire complex under a

single new mechanical system. The savings on energy costs is expected to approach $1 million by 1997.

Sonoma County Cuts Utility Bill

Sonoma County, California, has enjoyed this kind of cost savings since 1989, when it began operating a 650,000-gallon (2,457,000-liter) chilled-water storage system at its nine-building Sonoma County Administration Center in Santa Rosa. Previously, each building had its own chiller, with a total cooling capacity of about 1200 tons (4220 kilowatt-hours). (A "ton" of cooling is 12,000 Btu [3.52 kilowatts] per hour of useful heat removal—the cooling that would be provided by 1 ton [0.9 metric ton] of ice melting at 32°F [0°C] in 24 hours. The term is a carryover from the days when ice was used for cooling.) Now the nine buildings are cooled from a central mechanical plant with a capacity of only 780 tons (2743 kilowatt-hours). This central plant achieves greater efficiency by running closer to optimum capacity.

Sonoma County's chilled-water storage system cut the Administration Center's utility bill in half and earned a $250,000 rebate from the local utility. The new system also saved an estimated $8,000 a year in maintenance costs because it needs about half as much chiller capacity as the old systems.

Phase-Change Materials Cool Storage

Phase-change materials are the new kids on the cool storage block, although they've been around in their present form since the early 1980s. Phase-change materials are salts developed to undergo liquid/solid phase changes at temperatures as high as 47°F (8°C), and to store and release large amounts of energy during the phase change. Stored in hermetically sealed plastic containers, phase-change materials change to solids as they release heat to chilled water that flows around them. At these temperatures, chillers can operate more efficiently than at the low temperatures required by ice storage systems. Phase-change materials also store about three times more Btu per pound (joules per kilogram) than a typical chilled-water storage system.

Anaheim Public Utilities in Anaheim, California, recently became the first city-owned utility to embrace this technology. Anaheim has a 7-year, pay-per-performance contract with Transphase Systems, Inc., of Huntington Beach, to provide enough phase-change material cool storage systems to shift 6 megawatts off-peak.

"The choice of ice, chilled water, or PCMs depends on what's needed," says Don Gascoigne, Transphase sales manager. "If low temperatures are needed, something like ice is best. If there are conventional temperatures and plenty of space, chilled water can be installed. If space is limited, low temperatures aren't required, and a passive, easy-to-maintain system is desired, ours is a good choice."

Conclusion

Whether you "store cold" with ice, chilled water, or phase-change materials, cool storage can help balance the daily ups and downs of electrical power consumption. The technology is straightforward and proven, and the savings can be substantial. Cool storage is one of the most powerful tools available to utilities for balancing their power loads and to local governments and private businesses for cutting energy costs and promoting more efficient energy use in their communities. ■

For More Information

Public Technology, Inc.
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Application Guide for Thermal Energy Storage, document no. 87-302. A comprehensive introduction to thermal energy storage.

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EPRI HVAC&R Center
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A source of research and technical advice on cool storage, this center also offers seminars and will contract to review plan specifications for cool storage projects.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329
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The ASHRAE Journal
ASHRAE Design Guide for Cool Thermal Energy Storage

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